

configurations of the bottom layer in which stitching yarn pairs stitch the bottom MD yarns can be used. It is also contemplated that, rather than including a pair of stitching yarns between each pair of top CMD yarns, a fabric in which a pair of stitching yarns is included between every other pair of top CMD yarns can be constructed. In addition, although the illustrated fabrics have equal numbers of top and bottom MD and CMD yarns, this need not be the case for the present invention; other ratios, such as two top CMD yarns for each bottom CMD yarn, can also be employed.

The configurations of the individual yarns utilized in the fabrics of the present invention can vary, depending upon the desired properties of the final papermakers' fabric. For example, the yarns may be multifilament yarns, monofilament yarns, twisted multifilament or monofilament yarns, spun yarns, or any combination thereof. Also, the materials comprising yarns employed in the fabric of the present invention may be those commonly used in papermakers' fabric. For example, the yarns may be formed of cotton, wool, polypropylene, polyester, aramid, nylon, or the like. The skilled artisan should select a yarn material according to the particular application of the final fabric.

Regarding yarn dimensions, the particular size of the yarns is typically governed by the size and spacing of the papermaking surface. Generally, the diameter of the top CMD yarns is about 25 to 75 percent of the diameter of the bottom CMD yarns, and the diameter of the top MD yarns is about equal to or smaller than the diameter of the top CMD yarns. In a typical fabric, the diameter of the top CMD yarns is between about 0.11 and 0.17 mm, the diameter of the top MD yarns is between about 0.11 and 0.15 mm, the diameter of the bottom CMD yarns is between about 0.20 and 0.40 mm, and the diameter of the bottom MD yarns is between about 0.17 and 0.25 mm. The diameter of the stitching yarns is typically between about 0.11 and 0.17 mm.

Yarns may also vary advantageously in modulus of elasticity. For example, stitching yarns that interweave with a fewer number of top MD yarns than its paired stitching yarn (such as the "b" yarns of fabric 20) may have a higher modulus of elasticity (typically between about 10 and 50 percent higher) than its paired stitching yarn.

As the foregoing discussion demonstrates, the fabrics of the present invention address problems encountered with prior art triple layer forming fabrics. The fabrics of the present invention integrate the stitching yarns into the top surface of the fabric, whether it be a plain weave, a twill, a satin, or other pattern, and therefore avoid the marring of the papermaking surface that can accompany stitching yarns that comprise less of the papermaking surface. The integration of the fabric attributable to the stitching yarns also greatly reduces (if not eliminating) interlayer wear. In addition, because the stitching yarns comprise such a large portion of the papermaking surface, the differences in tension between the top CMD yarns and the stitching yarns that can distort the papermaking surfaces of other fabric are less critical to the fabrics of the present invention. The density of the stitching yarns also provides a tighter and more reliable binding of the top and bottom layers of the fabric, which can provide the designer with a wider variety of yarn choices to balance paper forming properties, durability and wear.

The foregoing embodiments are illustrative of the present invention, and are not to be construed as limiting thereof. The invention is defined by the following claims, with equivalents of the claims to be included therein.

That which is claimed:

1. A papermaker's fabric, comprising top machine direction yarns, top cross machine direction yarns, bottom

machine direction yarns, bottom cross machine direction yarns, and sets of first and second stitching yarns, said fabric being formed in a plurality of repeating units, each of said repeating units comprising:

a set of top machine direction yarns;

a set of top cross machine direction yarns interwoven with said set of top machine direction yarns;

a set of bottom machine direction yarns;

a set of bottom cross machine direction yarns interwoven with said set of bottom machine direction yarns;

wherein a pair of first and second stitching yarns is positioned between each adjacent pair of top cross machine direction yarns, said first and second stitching yarns of each pair being interwoven with said top and bottom machine direction yarns such that, as a fiber support portion of said first stitching yarn is interweaving with said top machine direction yarns, a binding portion of said second stitching yarn is positioned below said top machine direction yarns, and such that as a fiber support portion of said second stitching yarn is interweaving with said top machine direction yarns, a binding portion of said first stitching yarn is positioned below said top machine direction yarns, and such that said first and second stitching yarns cross each other as they pass below a transitional top machine direction yarn, and such that each of said binding portions of said first and second stitching yarns passes below at least one of said bottom machine direction yarns;

wherein each of said top cross machine direction yarns passes over a first group of alternate top machine direction yarns and under a second group of alternate top machine direction yarns, with each of said yarns of said first group being positioned between a pair of yarns of said second group, and with each of said yarns of said second group being positioned between a pair of yarns of said first group, and wherein said fiber support portions of said first and second stitching yarns pass under said first set of alternate top machine direction yarns and over said second set of alternate top machine direction yarns, such that said top machine direction yarns, said top cross machine direction yarns, and said fiber support portions of said first and second stitching yarns form a plain weave pattern;

wherein said fiber support portions of said first stitching yarns pass over a first number of said machine direction yarns, said fiber support portions of said second stitching yarns pass over a second number of said machine direction yarns, and said first number differs from said second number.

2. The papermaker's fabric defined in claim 1, wherein said first number is larger than said second number, and wherein said second stitching yarn has a higher modulus of elasticity than said first stitching yarn.

3. The papermaker's fabric defined in claim 1, wherein said first number is three, and second number is two.

4. The papermaker's fabric defined in claim 1, wherein said first and second stitching yarns are of a smaller diameter than said top machine direction yarns.

5. A papermaker's fabric, comprising top machine direction yarns, top cross machine direction yarns, bottom machine direction yarns, bottom cross machine direction yarns, and sets of first and second stitching yarns, said fabric being formed in a plurality of repeating units, each of said repeating units comprising:

a set of top machine direction yarns;

a set of top cross machine direction yarns interwoven with said set of top machine direction yarns;
a set of bottom machine direction yarns;

a set of bottom cross machine direction yarns interwoven with said set of bottom machine direction yarns;
wherein a pair of first and second stitching yarns is positioned between each adjacent pair of top cross machine direction yarns, said first and second stitching yarns of each pair being interwoven with said top and bottom machine direction yarns such that, as a fiber support portion of said first stitching yarn is interweaving with said top machine direction yarns, a binding portion of said second stitching yarn is positioned below said top machine direction yarns, and such that as a fiber support portion of said second stitching yarn is interweaving with said top machine direction yarns, a binding portion of said first stitching yarn is positioned below said top machine direction yarns, and such that said first and second stitching yarns cross each other as they pass below a transitional top machine direction yarn, and such that each of said binding portions of said first and second stitching yarns passes beneath only one of said bottom machine direction yarns.

6. A papermaker's fabric, comprising top machine direction yarns, top cross machine direction yarns, bottom machine direction yarns, bottom cross machine direction yarns, and sets of first and second stitching yarns, said fabric being formed in a plurality of repeating units, each of said repeating units comprising:

a set of top machine direction yarns;
a set of top cross machine direction yarns interwoven with said set of top machine direction yarns;
a set of bottom machine direction yarns;
a set of bottom cross machine direction yarns interwoven with said set of bottom machine direction yarns;

wherein a pair of first and second stitching yarns is positioned between each adjacent pair of top cross machine direction yarns, said first and second stitching yarns of each pair being interwoven with said top and bottom machine direction yarns such that, as a fiber support portion of said first stitching yarn is interweaving with said top machine direction yarns, a binding portion of said second stitching yarn is positioned below said top machine direction yarns, and such that as a fiber support portion of said second stitching yarn is interweaving with said top machine direction yarns, a binding portion of said first stitching yarn is positioned below said top machine direction yarns, and such that said first and second stitching yarns cross each other as they pass below a transitional top machine direction yarn, and such that each of said binding portions of said first and second stitching yarns passes below at least one of said bottom machine direction yarns,

wherein said repeat unit includes 10 top machine direction yarns and 10 bottom machine direction yarns.

7. A papermaker's fabric, comprising top machine direction yarns, top cross machine direction yarns, bottom machine direction yarns, bottom cross machine direction yarns, and sets of first and second stitching yarns, said fabric being formed in a plurality of repeating units, each of said repeating units comprising:

a set of top machine direction yarns;
a set of top cross machine direction yarns interwoven with said set of top machine direction yarns;

a set of bottom machine direction yarns;
a set of bottom cross machine direction yarns interwoven with said set of bottom machine direction yarns;

wherein a pair of first and second stitching yarns is positioned between each adjacent pair of top cross machine direction yarns, said first and second stitching yarns of each pair being interwoven with said top and bottom machine direction yarns such that, as a fiber support portion of said first stitching yarn is interweaving with said top machine direction yarns a binding portion of said second stitching yarn is positioned below said top machine direction yarns, and such that as a fiber support portion of said second stitching yarn is interweaving with said top machine direction yarns, a binding portion of said first stitching yarn is positioned below said top machine direction yarns, and such that said first and second stitching yarns cross each other as they pass below a transitional top machine direction yarn, and such that each of said binding portions of said first and second stitching yarns passes below at least one of said bottom machine direction yarns;

wherein said top machine direction yarns and said top cross machine direction yarns are interwoven in a repeating pattern such that each of said top cross machine direction yarns passes over a first pair of adjacent top machine direction yarns, under a third top machine direction yarn adjacent to said first pair, and over a second pair of top machine direction yarns positioned adjacent said third top machine direction yarn, and wherein adjacent top cross machine direction yarns pass over top machine direction yarn pairs that are offset by two top machine direction yarns;

wherein said stitching yarns are interwoven with said top machine direction yarns in a repeating pattern such that said fiber support portion of each of said first and second stitching yarns passes over a third pair of adjacent top machine direction yarns, under an adjacent top machine direction yarn, and over a fourth pair of adjacent machine direction yarns, then passes under said transitional top machine direction yarn, said third and fourth pairs of top machine direction yarns being offset from said first and second pairs by one machine direction yarn, such that said top machine direction yarns, said cross machine direction yarns, and said fiber support portions of said first and second stitching yarns form a 1x2 twill pattern.

8. A papermaker's fabric, comprising top machine direction yarns, top cross machine direction yarns, bottom machine direction yarns, bottom cross machine direction yarns, and sets of first and second stitching yarns, said fabric being formed in a plurality of repeating units, each of said repeating units comprising:

a set of top machine direction yarns;
a set of top cross machine direction yarns interwoven with said set of top machine direction yarns;
a set of bottom machine direction yarns;
a set of bottom cross machine direction yarns interwoven with said set of bottom machine direction yarns;

wherein a pair of first and second stitching yarns is positioned between each adjacent pair of top cross machine direction yarns, said first and second stitching yarns of each pair being interwoven with said top and bottom machine direction yarns such that, as a fiber support portion of said first stitching yarn is interweaving with said top machine direction yarns, a binding

portion of said second stitching yarn is positioned below said top machine direction yarns, and such that as a fiber support portion of said second stitching yarn is interweaving with said top machine direction yarns, a binding portion of said first stitching yarn is positioned below said top machine direction yarns, and such that said first and second stitching yarns cross each other as they pass below a transitional top machine direction yarn, and such that each of said binding portions of said first and second stitching yarns passes below at least one of said bottom machine direction yarns;

wherein said stitching yarns are interwoven with said top and bottom machine direction yarns such that adjacent pairs of stitching yarns cross beneath transitional top machine direction yarns that are offset by two top machine direction yarns.

9. The papermaker's fabric defined in claim 8, wherein between 25 and 50 percent of said first and second stitching yarns are interwoven with said top machine direction yarns as reversed picks.

10. A papermaker's fabric, comprising top machine direction yarns, top cross machine direction yarns, bottom machine direction yarns, bottom cross machine direction yarns, and sets of first and second stitching yarns, said fabric being formed in a plurality of repeating units, each of said repeating units comprising:

a set of top machine direction yarns;

a set of top cross machine direction yarns interwoven with said set of top machine direction yarns;

a set of bottom machine direction yarns;

a set of bottom cross machine direction yarns interwoven with said set of bottom machine direction yarns;

wherein pairs of first and second stitching yarns are positioned between pairs of top cross machine direction yarns, said first and second stitching yarns of each pair being interwoven with said top and bottom machine direction yarns such that, as a fiber support portion of said first stitching yarn is interweaving with said top machine direction yarns, a binding portion of said second stitching yarn is positioned below said top machine direction yarns, and such that as a fiber support portion of said second stitching yarn is interweaving with said top machine direction yarns, a binding portion of said first stitching yarn is positioned below said top machine direction yarns, and such that said first and second stitching yarns cross each other as they pass below a transitional top machine direction yarn, and such that each of said binding portions of said first and second stitching yarns passes below at least one of said bottom machine direction yarns, and wherein between 25 and 50 percent of adjacent pairs of first and second stitching yarns are interwoven as reversed picks;

wherein each of said top cross machine direction yarns passes over a first group of alternate top machine direction yarns and under a second group of alternate top machine direction yarns, with each of said yarns of said first group being positioned between a pair of yarns of said second group, and with each of said yarns of said second group being positioned between a pair of yarns of said first group, and wherein a pair of first and second stitching yarns is positioned between each pair of top cross machine direction yarns, and wherein said fiber support portions of said first and second stitching yarns pass under said first set of alternate top machine

direction yarns and over said second set of alternate top machine direction yarns, such that said top machine direction yarns, said top cross machine direction yarns, and said fiber support portions of said first and second stitching yarns form a plain weave pattern;

wherein said fiber support portions of said first stitching yarns pass over a first number of said machine direction yarns, said fiber support portions of said second stitching yarns pass over a second number of said machine direction yarns, and said first number differs from said second number.

11. The papermaker's fabric defined in claim 10, wherein said first number is larger than said second number, and wherein said second stitching yarn has a higher modulus of elasticity than said first stitching yarn.

12. The papermaker's fabric defined in claim 10, wherein said first number is three, and second number is two.

13. A papermaker's fabric, comprising top machine direction yarns, top cross machine direction yarns, bottom machine direction yarns, bottom cross machine direction yarns, and sets of first and second stitching yarns, said fabric being formed in a plurality of repeating units, each of said repeating units comprising:

a set of top machine direction yarns;

a set of top cross machine direction yarns interwoven with said set of top machine direction yarns;

a set of bottom machine direction yarns;

a set of bottom cross machine direction yarns interwoven with said set of bottom machine direction yarns;

wherein pairs of first and second stitching yarns are positioned between pairs of top cross machine direction yarns, said first and second stitching yarns of each pair being interwoven with said top and bottom machine direction yarns such that, as a fiber support portion of said first stitching yarn is interweaving with said top machine direction yarns, a binding portion of said second stitching yarn is positioned below said top machine direction yarns, and such that as a fiber support portion of said second stitching yarn is interweaving with said top machine direction yarns, a binding portion of said first stitching yarn is positioned below said top machine direction yarns, and such that said first and second stitching yarns cross each other as they pass below a transitional top machine direction yarn, and such that each of said binding portions of said first and second stitching yarns passes below at least one of said bottom machine direction yarns, and wherein between 25 and 50 percent of adjacent pairs of first and second stitching yarns are interwoven as reversed picks;

wherein said repeat unit includes 12 top machine direction yarns and 12 bottom machine direction yarns.

14. A method of making paper, said method comprising the steps of:

(a) providing a papermaker's fabric comprising top machine direction yarns, top cross machine direction yarns, bottom machine direction yarns, bottom cross machine direction yarns, and sets of first and second stitching yarns, said fabric being formed in a plurality of repeating units, each of said repeating units comprising:

a set of top machine direction yarns;

a set of top cross machine direction yarns interwoven with said set of top machine direction yarns;

a set of bottom machine direction yarns;

a set of bottom cross machine direction yarns interwoven with said set of bottom machine direction yarns;

wherein a pair of first and second stitching yarns is positioned between each adjacent pair of top cross machine direction yarns, said first and second stitching yarns of each pair being interwoven with said top and bottom machine direction yarns such that, as a fiber support portion of said first stitching yarn is interweaving with said top machine direction yarns, a binding portion of said second stitching yarn is positioned below said top machine direction yarns, and such that as a fiber support portion of said second stitching yarn is interweaving with said top machine direction yarns, a binding portion of said first stitching yarn is positioned below said top machine direction yarns, and such that said first and second stitching yarns cross each other as they pass below a transitional top machine direction yarn, and such that each of said binding portions of said first and second stitching yarns passes below at least one of said bottom machine direction yarns;

wherein each of said top cross machine direction yarns passes over a first group of alternate top machine direction yarns and under a second group of alternate top machine direction yarns, with each of said yarns of said first group being positioned between a pair of yarns of said second group, and with each of said yarns of said second group being positioned between a pair of yarns of said first group, and wherein said fiber support portions of said first and second stitching yarns pass under said first set of alternate top machine direction yarns and over said second set of alternate top machine direction yarns, such that said top machine direction yarns, said top cross machine direction yarns, and said fiber support portions of said first and second stitching yarns form a plain weave pattern;

wherein said fiber support portions of said first stitching yarns pass over a first number of said machine direction yarns, said fiber support portions of said second stitching yarns pass over a second number of said machine direction yarns, and said first number differs from said second number;

- (b) applying paper stock to said papermaker's fabric; and
- (c) removing moisture from said paper stock.

15. A method of making paper, said method comprising the steps of:

- (a) providing a papermaker's fabric comprising top machine direction yarns, top cross machine direction yarns, bottom machine direction yarns, and sets of first and second stitching yarns, said fabric being formed in a plurality of repeating units, each of said repeating units comprising:

a set of top machine direction yarns;

a set of top cross machine direction yarns interwoven with said set of top machine direction yarns;

a set of bottom machine direction yarns;

a set of bottom cross machine direction yarns interwoven with said set of bottom machine direction yarns;

wherein a pair of first and second stitching yarns is positioned between each adjacent pair of top cross machine direction yarns, said first and second stitching yarns of each pair being interwoven with said top and bottom machine direction yarns such that, as a fiber support portion of said first stitching yarn is interweaving with said top machine direction yarns, a binding portion of said second stitching yarn is positioned below said top machine direction yarns, and such that as a fiber support portion of said second stitching yarn is interweaving with said top machine direction yarns, a binding portion of said first stitching yarn is positioned below said top machine direction yarns, and such that said first and second stitching yarns cross each other as they pass below a transitional top machine direction yarn, and such that each of said binding portions of said first and second stitching yarns passes below at least one of said bottom machine direction yarns;

wherein said top machine direction yarns and said top cross machine direction yarns are interwoven in a repeating pattern such that each of said top cross machine direction yarns passes over a first pair of adjacent top machine direction yarns, under a third top machine direction yarn adjacent to said first pair, and over a second pair of top machine direction yarns positioned adjacent said third top machine direction yarn, and wherein adjacent top cross machine direction yarns pass over top machine direction yarn pairs that are offset by two top machine direction yarns,

and wherein said stitching yarns are interwoven with said top machine direction yarns in a repeating pattern such that said fiber support portion of each of said first and second stitching yarns passes over a third pair of adjacent top machine direction yarns, under an adjacent top machine direction yarn, and over a fourth pair of adjacent machine direction yarns, then passes under said transitional top machine direction yarn, said third and fourth pairs of top machine direction yarns being offset from said first and second pairs by one machine direction yarn, such that said top machine direction yarns, said cross machine direction yarns, and said fiber support portions of said first and second stitching yarns form a 1x2 twill pattern;

- (b) applying paper stock to said papermaker's fabric; and
- (c) removing moisture from said paper stock.

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